Tabiscope: Mobile Device Camera Connector

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1. Background

Endoscopes are used in a variety of medical specialties, from otolaryngology to obstetrics and gynecology and even gastroenterology. Doctors use endoscopes in order to get a better glimpse of the internal linings of the human body. In otolaryngology, the doctor places the tip of the scope into the nose and starts in the nasal cavity. From here, the doctor pushes the scope further into the patient to examine the rest of the airways.

In order to facilitate patient examination, companies such as Olympus and Stryker have created cameras that are capable of attaching onto the eyepiece of an endoscope. This allows the physician to look at a larger image of the scopes view. Additionally, it also frees the doctor to stand and interact with the patient normally while still performing the examination. The processing capabilities of the imaging tower make it possible to enhance images as well.

2. Problem

Imaging towers used for endoscopic procedures cost thousands of dollars. Due to financial issues, most emergency departments do not have a dedicated tower and have to wait for one from another department. This waiting period is a waste of time, and can be detrimental for some patients. Furthermore, the towers are large, on the order of five feet in height and one foot in the other dimensions. Thus, they occupy a significant amount of space, and are not easy to transport around. In order to solve the problem of cost and ease of mobility, it is beneficial to design a low-cost portable method for recording images. Along with that, this method also needs to have a way to securely send the recorded images to physicians who are not present during the procedure.

Endoscopy is an invasive procedure that causes trauma to patients. In a scenario where an attending physician is not at the hospital or specialist is asked for a consult, he has to perform another procedure. Repeated endoscopies can lengthen a patient’s stay due to the extra trauma. In order to reduce this problem, physicians need a method of recording and transmitting images securely and easily. Some physicians have reported using their cellphones in order to take pictures and text them to their colleagues for immediate consultation. This method is not secure and a better way is necessary for immediate transmission of data.

As mentioned earlier, imaging towers are worth thousands of dollars. Given this, rural hospitals and hospitals that serve low income areas and many hospitals in third world countries are not likely to have many towers. This limits the number of simultaneous procedures and total number of procedures that can happen. A low cost alternative with similar functionalities will help improve the amount of care given. Also, increasing the portability will allow such functionality in places such as rural villages in India.
As seen above, there is a clear need for a system that is easy to move around. Additionally, this system has to be low cost to be accessible to the vast majority of health providers.

3. Methods

The hardware was designed in order to facilitate interaction between an Asus Android tablet and an endoscope. To meet the requirements for being low cost, the adapter is made out of acrylic and 3D printed parts. The physician uses the pair of clamps on the attachment to hold the tablet in position. These clamps are adjustable in order to allow the user to change the tablet's position. The endoscope is attached to the other side in its holding piece. This piece allows the user to rotate the endoscope while conducting the procedure. Additionally, in order to secure the endoscope, there are pieces that press fit into the holder to ensure that the scope does not fall out. Future work can focus on creating an ergonomic handle to permit higher quality ease of use.

The software has two components, a front-end graphical user interface and a back-end video streaming and image capture part. The user interface was designed to allow doctors the ability to draw on captured images to indicate the position of notable structures. The software preserves original unedited image as well as the annotated image with the overlaid markings. It also permits the ability to create typed notes. When a physician returns later to view the study, he can access both the images and the attached notes to make further changes. The interface also permits the user to adjust the settings for the camera. A few of the settings include the ISO, the focus, and the zoom. Finally, although not part of the user interface in the current application, a doctor should be able to use it to attach a saved annotated image with its associated data (such as text notes) to their work emails and send them to colleagues for review. Future work can focus on creating an embedded way to upload captured files on to a shared, HIPAA compliant server.

On the back-end side, the application is designed to permit real-time viewing of endoscopic images. The software detects the circular image and expands it to fill up the entire screen. Due to the diminished processing capabilities of smartphones and tablet, the image on screen is a low resolution image to permit quick processing. However, there is a second high resolution video stream that is stored into the handheld's memory. Any saved images are also extracted from the higher resolution stream. This back end is also responsible for taking the user input and manipulating the camera to the user's specifications. A feature that is currently unavailable is the ability to remove specular reflections off the images and doing it in real time. Specular reflection occurs when the light from the endoscope's light source hits a moist surface and returns back to the scope. Future work and the improvements in tablet processors will allow the application to account for this specular reflection. Future work could also try creating a new algorithm based on difference in brightness to determine the appropriate zoom for getting the tablet camera image to fill the entire screen.

Image taken while holding tablet's camera directly to endoscope

4. Hardware Approach

4.1 Specifications

The hardware is made out of acrylic as well as 3D printed ABS. It is designed to serve as the interface between an Android tablet such as the Asus Infinity Pad and an endoscope. The tablet goes on one side while the endoscope attaches on the other side. By making a physician hold a tablet during a procedure, it becomes a little awkward to use the scope due to the weight and size. Thus, it is necessary than any adapter have as little weight as possible to prevent making it more cumbersome.

4.2 Dependencies

In order to manufacture the adapter, the team required access to a 3D printer as well as a laser cutter. The 3D printer was used to manufacture the endoscope and the tablet clamps. The laser cutter was used to manufacture the base plate. However, it is possible to create the base plate with a hand saw, a dremel and a drill.

4.3 Baseplate

The baseplate is the part of the adapter that is responsible for providing support for the tablet. It serves as the rigid structure between the tablet and endoscope. Additionally, it is the piece to which the rest of the parts attach. This piece is made using acrylic sixteenth of an inch thick. This thickness does not add significant amounts of weight, and is still rigid enough not to flex without a significant amount of force applied. In order to lower the weight, there are lightening holes laser cut into the piece. These holes are designed to keep the core structural areas intact for the best possible support.

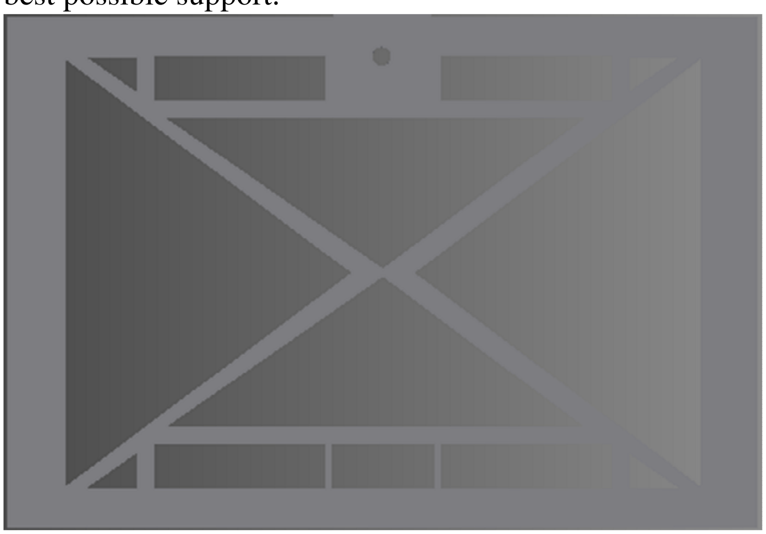


Image depicts the baseplate of the adapter

4.4 Endoscope clamp

The endoscope clamp is a square piece of extruded ABS with two holes in it. There is a large hole of a sufficient diameter in order to hold the scope tightly while still allowing enough freedom for the scope to rotate. There is another, smaller hole at the center of the clamp for the endoscope's viewing hole. In order to assemble the clamp onto the base plate, one just has to line up the viewing holes and use an adhesive such as acrylic glue to attach the pieces.

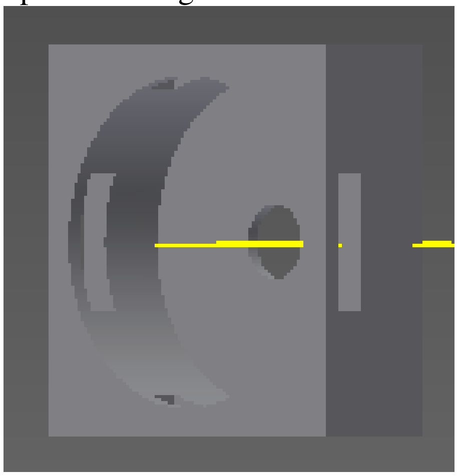


Image depicts the endoscope clamp

4.5 Tablet clamps

The two tablet clamps are also made out of extruded ABS plastic. They are designed to clamp onto both sides of the tablet. It does not span the entire length of the tablet, but only the first inch and a half. The reasoning behind this is to reduce the weight. The clamps are attached to the baseplate using one 8-32 hex head screw each. Furthermore, the baseplate has two rectangular holes for the screws. This allows the user to adjust the position of the clamps in order to line up the tablet's camera with the endoscope and to fit a tablet of a different size.

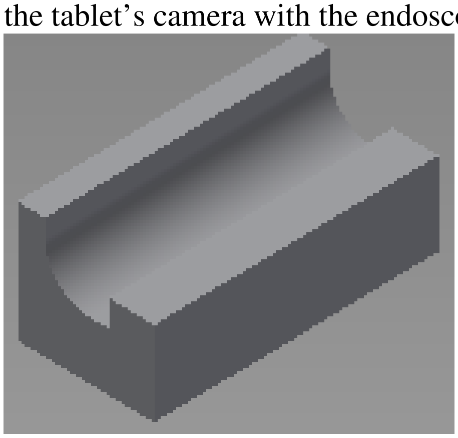


Image depicts one of two tablet clamps

4.6 How to Use

4.6.1 Before Use

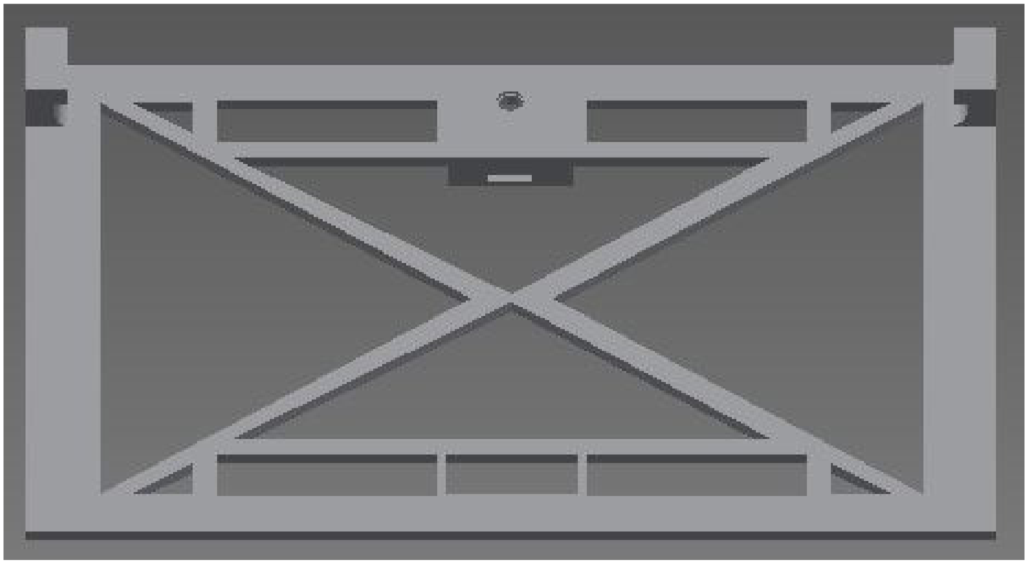
The doctor first has to insert the tablet by sliding it into the tablet clamps. Then, he should adjust the clamps by sliding them until they are tight up against the tablet. After that, he should tighten the screws until the clamps no longer slide. Finally, the doctor inserts the scope into its clamp and can use the optional securing pins to get a better hold.

4.6.2 After Use

After a procedure, the endoscope is removed by twisting it and angling the scope so that it pops out of the endoscope clamp. If the securing pins were used, they should be removed first. After the scope is removed, the physician needs to loosen the screw on the tablet clamps in order to remove the tablet.

4.7 Cleaning

Cleaning the adapter is possible by using alcohol and gauze swabs to wipe down the surfaces. Testing needs to occur as to whether the device is suited for an autoclave.



A CAD model of the entire tablet adapter

5. Software Approach

5.1 Android Programming

The Android Operating System is an open source system whose code is available through Google. In addition, the company provides an integrated development environment in order to create applications. For use with other IDEs, Google provides an Android SDK for download. Along with this, the Eclipse IDE has a plugin that permits Android programming. Other IDEs will have their own downloadable content to permit programming.

5.2 Dependencies

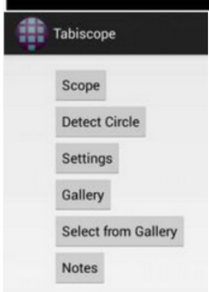
In order to test the code, one will need an Android device. The team used both a tablet as well as a cellphone to permit simultaneous testing of the camera settings and the user interface. The team obtained an Asus Transformer Pad Infinity as well as a Samsung cellphone.

5.3 Camera Control

There are certain aspects of the camera that need to be controlled in order to achieve good image quality for video and pictures. These include settings such as manipulating the ISO, changing the zoom, tuning the focus and a few other settings. In order to do this, the user has the option of sliding bars in order to change the value of the settings. Each one gets its own unique sliding bar.

Once the user has found the desired settings, they have the option of locking them so that they do not inadvertently change. Additionally, there is an option for the camera to automatically adjust its settings. This lowers the number of variables a physician has to worry about.

The top of the image has the camera controls that the user has access to in the app.



This image shows the initial menu of the application

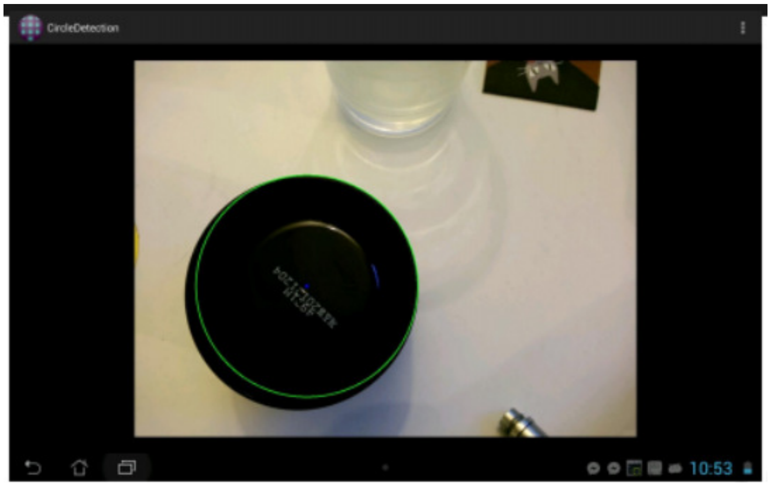
5.4 Circle Detection

When the application is first started, the image seen on the screen is that of the circle created by the endoscope's eyepiece. In order to minimize the number of actions the user performs, the team worked on a method for automatically detecting the circle and expanding it to fill the entire screen. This is possible through the use of the Hough Transformation for circles.

According to the lecture by Harvey Rhody at the Rochester Institute of Technology, a circle is parameterized by the following equations:

$$x = a + Rcos(\theta), y = b + Rsin(\theta)$$

The R represents the radius of the circle in question, while a and b are the coordinates for the center of the circle. The transform is used to calculate the three variables that define the circle. It is not necessary to calculate theta because in order to define a full circle, the program needs to use all values from 0 to 360. OpenCV has a Hough Circle Transform function that can figure out the three parameters. It first converts the images to grayscale and applies a Gaussian blur that distorts the image. This helps avoid any false positive circles by reducing the noise. After blurring the image, the transform is applied and displays any found circles. Testing has shown that the OpenCV transform is reliable in detecting circles. A user can manipulate the threshold parameters in order to improve the detection capabilities. Once the endoscope image circle is found, the team expands the circle to fill the screen of the tablet.



The green circle represents the detected circle in the image. Not a perfect detection, but fairly good

5.5 Dual Stream

The team decided to use a dual image stream in the application. Image processing is a memory intensive procedure, and the higher the quality, the more memory required. In order to do circle detection and other image corrections, the team uses a low resolution stream that outputs to the user visible screen. The low resolution permits easier real time image processing so that the physician does not experience large amounts of lag between moving the scope and seeing the resultant image. However, the low resolution stream is not optimal for medical imaging. It does not allow physicians the clarity required to notice any problems with the patients. So, when the user wants to save videos and images of the procedures, the saved images are acquired from the high resolution stream.

5.6 Drawing on Images

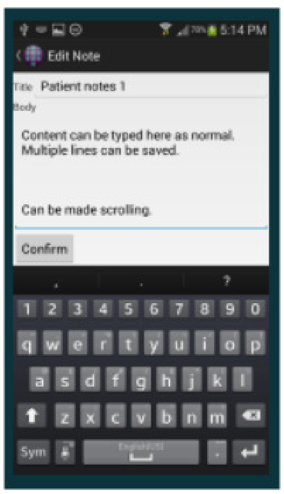
A feature of the product is the ability to draw on the images. In the process of performing a procedure, a physician might notice a peculiarity or something that he wants to revisit later. The team added a drawing feature to the application that lets the doctor mark the video or picture. These annotated images are saved in addition to the original image. Our application can also link to other Android image editing applications such as Skitch or Photoshop Express to use to edit the image in other ways.

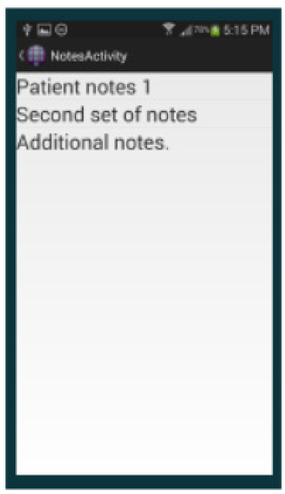
This image shows how it is possible to draw on an image in order to highlight interesting pathology

5.7 Adding Notes to Images

The application also permits users to type up notes that will be associated with the images. This function works similar to the notes application currently found on Android devices.
Further specifications would be to create separate fields for:
- Date/time (current date/time based on time zone such as 7:19am May 9, 2014)
- Patient ID (a searchable text string that could just be the name, or it could be a generated number id such as 278)
- Patient Name (First and last)
- Patient DOB (such as August 13, 1991)
- Medical record number (such as 570422)

Physicians also get the opportunity to type up the notes when they are reviewing the study. Future work can create a data structure to store the image, associated notes and corresponding drawings together.





Example of the interface for creating notes

6. Management Summary

6.1 Division of Labor

All three members participated in the planning of the project and determining deadlines for the deliverables. This holds true for the maintenance of the website and creation of presentations. Given Deepak's prior work with mechanically related projects, he was tasked with creating the adapter between the tablet and the endoscope. Since Kyle and Daniel had more experience with program and the Android platform, they were tasked with the programming aspect. Daniel had taken a course in computer vision, so he took over the coding for controlling the camera and processing the images. This left Kyle with creating the graphical user interface and coding the ability to draw on the images and associate notes with them as well.

The team originally met with mentor Dr. Amit Kochhar in order to learn about his requirements and thoughts about the project. Initial specifications were outlined and the team was given flexibility for other aspects. Next, the team met with mentor Kevin Olds to discuss the plan of action, where the division of tasks occurred. Also, weekly meetings were scheduled with Kevin in order to keep track of progress and get questions answered. Contact was made with Dr. Kochhar periodically in order to keep him abreast of ongoing work and get updated specifications back from him.

6.2 Accomplished

The deliverables constantly changed with the updates from the medical team and the time constraints due to other classes as well. For the adapter, the original plan was to create a universal adapter that fit any tablet. Then, there was an attempt to switch to connect an external camera to the endoscope and then to use the tablet to process the imaging from the external camera. However, in the end, we decided to conclude this project with an adapter that fit the Asus Transformer Infinity with the ability to use the clamps on the tablet to adjust the position of the tablet. This was easier than investing time hacking into the internal Asus kernel to create drivers to processing an external cameras image feed on the tablet. On the software side, the team managed to record images from an endoscope and display them onto the tablet screen. In addition, the user has the ability to adjust camera settings, add notes and draw on the images. These are some of the functionalities discussed in the original meetings along with added features and specifications that were brought up while the project continued.

6.3 Future Work

One of the aspects that was not accomplished during this semester was the implementation of a secure method of uploading images and videos to a common server. From here doctors anywhere could login on a computer and see the images. Another feature for future work is to have a frame by frame video playback that allows the user to save the frames he wants. Additionally, another possible feature is recording the sound during a procedure, allowing the physician to verbally make notes or describe what is being seen and recorded. Further work could also be invested in creating a new algorithm for detecting the endoscope's field of view such as by comparing pixel brightness and finding the circle of the endoscopic image that way. Along with that, further imaging functionality could be added such as adjusting color balance, fixing specular reflection, and adjusting the image brightness. Finally, another future project is work on a portable light source to attach to the endoscopes. This will create a completely portable system for use in the field.

6.4 Lessons Learned

The reason the team did not have an external camera is that there was trouble with obtaining drivers for the camera. It might have meant writing drivers for the Android operating system. In the future, teams need to make sure they have someone who has experience working at the operating system's lower levels. Another lesson learned is that it is important to keep a written list of features and check them off when complete. Without such a list, it becomes difficult to know what still needs to be done and what work should be prioritized as the list of possible features continues to grow and change. In addition, it is important to keep in mind how manufacturing can take longer than expected. It would help to have someone with training and permission to use the tools in the engineering machine shop. A way to bypass this is to have a clearer idea of the goals earlier on. The switch between using the tablet to using an external camera and back to the tablet meant that the design process got extended. This meant that being able to manufacture the adapter got pushed back. One way to go around this was to keep modifying the part using CAD software, thus limiting the amount of money spent on manufacturing.

7. Acknowledgements

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8. References

- Duda, Richard O., and Peter E. Hart. "Use of the Hough transformation to detect lines and curves in pictures." Communications of the ACM 15.1 (1972): 11-15.
- Nayar, Shree K., Xi-Sheng Fang, and Terrance Boult. "Separation of reflection components using color and polarization." *International Journal of Computer Vision* 21.3 (1997): 163-186.
- Oh, JungHwan, et al. "Informative frame classification for endoscopy video." *Medical Image Analysis* 11.2 (2007): 110-127.
- Stehle, Thomas. "Removal of specular reflections in endoscopic images." *Acta Polytechnica* 46.4 (2006).
- Kaup, André, Katrin Meisinger, and Til Aach. "Frequency selective signal extrapolation with applications to error concealment in image communication." *AEU-International Journal of Electronics and Communications* 59.3 (2005).
- Levitan, Richard M., Ted S. Goldman, Donald A. Bryan, Frances Shofer, and Andrew Herlich. "Training with Video Imaging Improves the Initial Intubation Success Rates of Paramedic Trainees in an Operating Room Setting." *Annals of Emergency Medicine* 37.1 (2001): 46-50. Print.
- Ayoub, C. M., E. Kanazi, A. Al Alami, C. Ramesh, and M. F. El-Khatib. "Tracheal Intubation Following Training with the GlideScope Compared to Direct Laryngoscopy." *Journal of the Association of Anaesthesists of Great Britain and Ireland* 65.7 (2010): 674-78. *Wiley Online*. Web. 1 Apr. 2014.
- Rhody, Harvey. "Lecture 10: Hough Circle Transform." Web. 3 May 2014. <http://www.cis.rit.edu/class/simg782/lectures/lecture_10/lec782_05_10.pdf>.
- "Hough Circle Transform." Hough Circle Transform — OpenCV 2.4.9.0 Documentation. N.p., n.d. Web. 03 May 2014. <http://docs.opencv.org/doc/tutorials/imgproc/imgtrans/hough_circle/hough_circle.html>.